AD-A103 013 EDUCATIONAL TESTING SERVICE PRINCETON NJ F/G 12/1
AN UPPER ASYMPTOTE FOR THE THREE-PARAMETER LOGISTIC ITEM-RESPON--ETC(U)
JUL 81 M A BARTON, F M LORD N00014-80-C-0402
UNCLASSIFIED ETS-RR-81-20 NL

1 OF 1
AD
A103013

END
DATE
FILMED
9-81
DTIC

LEVEL II

12

RR-81-20

65

AD A103013

AN UPPER ASYMPTOTE FOR THE THREE-PARAMETER LOGISTIC ITEM-RESPONSE MODEL

Mark A. Barton
and
Frederic M. Lord

This research was sponsored in part by the
Personnel and Training Research Programs
Psychological Sciences Division
Office of Naval Research, under
Contract No. N00014-80-C-0402

Contract Authority Identification Number
NR No. 150-453

Frederic M. Lord, Principal Investigator

Educational Testing Service
Princeton, New Jersey

July 1981

81 8 18 001

12

AN UPPER ASYMPTOTE FOR THE THREE-PARAMETER LOGISTIC ITEM-RESPONSE MODEL

Mark A. Barton
and
Frederic M. Lord

This research was sponsored in part by the
Personnel and Training Research Programs
Psychological Sciences Division
Office of Naval Research, under
Contract No. N00014-80-C-0402

Contract Authority Identification Number
NR No. 150-453

Frederic M. Lord, Principal Investigator

Educational Testing Service
Princeton, New Jersey

July 1981

UNCLASSIFIED 14 RR-81-20

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Report 81-20	2. GOVT ACCESSION NO. AD-A103	3. RECIPIENT'S CATALOG NUMBER 013
4. TITLE (and Subtitle) An Upper Asymptote for the Three-Parameter Logistic Item-Response Model		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER Research Report 81-20
7. AUTHOR(s) Mark A. Barton, Frederic M. Lord		8. CONTRACT OR GRANT NUMBER(s) N00014-80-C-0402
9. PERFORMING ORGANIZATION NAME AND ADDRESS Educational Testing Service, Princeton, NJ 08541		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 150-453
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs, Office of Naval Research (Code 458), Arlington, VA 22217		12. REPORT DATE July 1981
		13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Item Response Theory
Item Characteristic Curve Theory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An upper-asymptote parameter was added to the three-parameter logistic item response model. This four-parameter model was compared to the three-parameter model on four data sets. The fourth parameter increased the likelihood in only two of the four sets. Ability estimates for the students were generally unchanged by the introduction of the fourth parameter.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

122 250

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

An Upper Asymptote for the Three-Parameter Logistic Item-Response Model

Mark A. Barton

and

Frederic M. Lord

Abstract

An upper-asymptote parameter was added to the three-parameter logistic item response model. This four-parameter model was compared to the three-parameter model on four data sets. The fourth parameter increased the likelihood in only two of the four sets. Ability estimates for the students were generally unchanged by the introduction of the fourth parameter.

An Upper Asymptote for the Three-Parameter Logistic Item-Response Model*

Mark A. Barton

and

Frederic M. Lord

A two-parameter logistic item-response model may be expressed as

$$F(\theta) = (1 + e^{-1.7a_g(\theta-b_g)})^{-1}$$

where $F(\theta)$ is the probability of a student with ability θ passing item g. The probability of passing ranges from zero to one as θ goes from $-\infty$ to ∞.

On a multiple choice test, however, the probability of choosing the correct answer does not approach zero for low-ability students. For this reason, a lower asymptote is introduced. The resulting three-parameter model is

$$G(\theta) = c + (1 - c)F(\theta)$$

where the lower asymptote, sometimes referred to as a guessing parameter, may be set arbitrarily; or a common value may be estimated from the data; or individual values may be estimated from the data separately for each item.

An upper asymptote may likewise be introduced into the model:

$$P(\theta) = c + (\delta - c)F(\theta) \quad .$$

While $F(\theta)$ ranges from zero to one, $P(\theta)$ ranges from the lower asymptote, c, to the upper asymptote, δ.

---

*This work was supported in part by contract N00014-80-C-0402, project designation NR150-453 between the Office of Naval Research and Educational Testing Service.

Even a high-ability student may make a clerical error in answering an easy item. The introduction of an upper asymptote with a value of slightly less than 1 should allow a high-ability student to miss an easy item without having his ability estimate drastically lowered.

This study of the upper-asymptote model was motivated largely by the concern that the three-parameter model might be severely penalizing high-ability students who make a clerical error on an easy item. The three-parameter model was compared to the upper-asymptote (four-parameter) model for four data sets: SAT Verbal, SAT Math, GRE Verbal, and AP Calculus AB.

The tests, all of which were developed by Educational Testing Service, are described briefly:

Scholastic Aptitude Test (SAT), Verbal: The SAT is a 75-minute, 90-item verbal test designed for applicants to undergraduate study. All items are five choice.

Scholastic Aptitude Test (SAT), Math: The mathematical part of the SAT (from a different form of the test, with different students) was analyzed as a separate data set. This 90-minute test has 85 items, 20 of which are four choice, and 65 of which are five choice.

Graduate Record Examination (GRE) Aptitude Test, Verbal: This test of verbal reasoning and reading comprehension is designed for applicants to graduate study. All of the items on this 50-minute, 80-item test are five-choice items.

<u>College Board Advanced Placement (AP) Examination--Mathematics</u>: <u>Calculus AB</u>: This is a test taken by high school students in order to receive college credit for their knowledge of elementary functions and first-semester calculus. The essay items were not included in this analysis. The objective portion lasts 90 minutes and has 45 items. All of the items are five choice.

For each of the four data sets, the following procedure was used:

1) Ability and item parameters were estimated under the three-parameter model using the program LOGIST (Wood & Lord, 1976; Wood, Wingersky, & Lord, 1976), with several thousand students. (These runs were already available.)

2) In order to reduce costs, a random subsample of 1000 students was chosen.

3) With the c_g parameters (guessing parameters) held fixed at the previously estimated values (to reduce costs), the remaining item parameters (a 's and b 's) and the abilities (θ 's) were reestimated for just the 1000 students with $\delta = 1.00$.

4) With the c_g parameters still held fixed, the a 's, b 's, and θ 's were estimated with upper asymptote values of $\delta = .99$ and $\delta = .98$, using a modified version of LOGIST on the sample of 1000 students.

The effect of the upper asymptote was measured in two ways. First, likelihoods were computed for each value of the upper asymptote ($\delta = 1.00$, $\delta = .99$, $\delta = .98$), and the asymptote value with the highest likelihood was considered the best fit. In two of the cases (GRE Verbal and AP Calculus AB) the highest likelihood was obtained with $\delta = 1.00$ (the standard three-parameter model) and in the other two cases (SAT Math and SAT Verbal) the highest likelihood was obtained with $\delta = .99$. In none of the four data sets did the highest and the lowest of the three log-likelihoods differ by more than 0.02% (more than .0002).

Second, ability estimates under the two asymptote values $\delta = 1.00$ and $\delta = .99$ were compared to see whether the change in upper-asymptote value had a large effect on the ability estimate of any individual student. Out of the 4000 students examined in the four data sets, the greatest change was an increase of .64 under the .99 upper-asymptote model. The five students most affected are summarized in Table 1. Two of these were very high-ability students, and the other three were very low-ability students. The ability estimate changed by more than the standard error of estimate in only one of the five cases. In all five cases, the .99-upper-asymptote model favored the student. The largest drop in a student's ability estimate under the .99-upper-asymptote model was .36, for a student of very low ability on the GRE Verbal. All 1000 students who took the GRE are plotted

Table 1

The Five Students with the Largest Absolute Changes

in T[illegible] out of 4000 Examined

$\theta_{\delta=1.00}$	$\theta_{\delta=.99}$	$\|\theta_{\delta=.99}-\theta_{\delta=1.00}\|$	Standard Error of Measurement of $\theta_{\delta=1.00}$	Test
2.9	3.4	0.5	0.4	GRE Verbal
2.8	3.3	0.5	0.7	AP Calculus AB
-3.9	-3.3	0.6	1.1	SAT Verbal
-5.0	-4.4	0.6	2.7	GRE Verbal
-5.9	-5.4	0.5	4.8	GRE Verbal

Thetas have a mean of 0 and a standard deviation of 1.

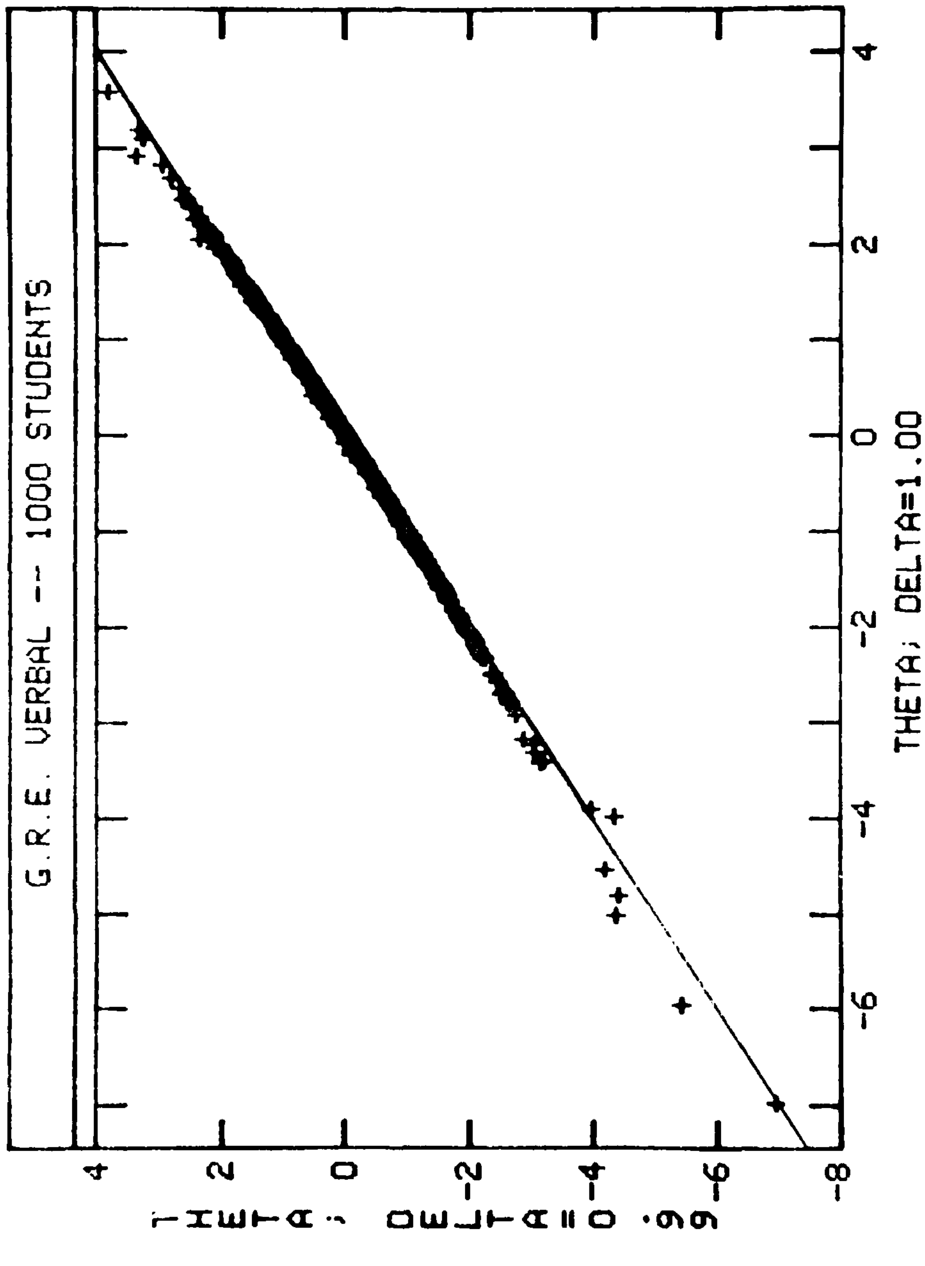
in Figure 1; in the plots for the other three data sets, points were even closer to the identity line.

One might expect more clerical errors to be made on a highly speeded test. This might result in the .99-upper-asymptote model fitting better than the 1.00-upper-asymptote model. The only highly speeded test of the four, the GRE Verbal, was fit best with the 1.00-upper-asymptote model, however, discounting this speededness hypothesis.

In view of the failure of the four-parameter model either to consistently improve the likelihood or to significantly change any ability estimates there is no compelling reason to urge the use of this model. The extra computational time required for the more complex derivatives further argues against its use.

One positive result of this study is that it suggests that the three-parameter logistic model does a better job of fitting high-ability students than some researchers (including the authors) had expected. Had we examined the normal-ogive model instead, which is less forgiving of incorrect answers to easy items by high-ability students, we would possibly have found a stronger case for the adoption of an upper asymptote of .99 or .98.

Figure 1


G.R.E. VERBAL -- 1000 STUDENTS
THETA; DELTA=1.00
THETA; DELTA=0.99
4
2
0
-2
-4
-6
-8

References

Lord, F. M. Applications of item response theory to practical testing problems. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1980.

Wood, R L, & Lord, F. M. A user's guide to LOGIST (ETS RM 76-4, modified). Princeton, N.J.: Educational Testing Service, 1976.

Wood, R L, Wingersky, M. S., & Lord, F. M. LOGIST - A computer program for estimating examinee ability and item characteristic curve parameters (ETS RM 76-6, modified). Princeton, N.J.: Educational Testing Service, 1976.

Appendix

Formulas for derivatives of the four-parameter model*:

n = number of items.

N = number of subjects.

$D = 1.7$.

δ = upper asymptote.

u_{ij} = observed response (1 if right, 0 if wrong) for item i , subject j .

$$L_{ij} = a_i(\theta_j - b_i) \quad .$$

$$P_{ij} = c_i + (\delta - c_i)/(1 + e^{-DL_{ij}}) \quad .$$

$$Q_{ij} = 1 - P_{ij} \quad .$$

The log likelihood is given by

$$\ell = \sum_{i=1}^{n} \sum_{j=1}^{N} [u_{ij} \ln P_{ij} + (1 - u_{ij}) \ln Q_{ij}] \quad . \qquad \text{(Lord, p. 58)}$$

Theta derivatives:

$$\frac{\partial \ell}{\partial \theta_j} = \sum_{i=1}^{n} (u_{ij} - P_{ij}) \frac{\left(\frac{\partial P_{ij}}{\partial \theta_j}\right)}{P_{ij}Q_{ij}}$$

and

$$\frac{\partial^2 \ell}{\partial \theta_j^2} = \sum_{i=1}^{n} \left[\frac{-\left(\frac{\partial P_{ij}}{\partial \theta_j}\right)^2}{P_{ij}Q_{ij}} + (u_{ij} - P_{ij}) \left[\frac{\left(\frac{\partial^2 P_{ij}}{\partial \theta_j^2}\right)}{P_{ij}Q_{ij}} + \frac{\left(\frac{\partial P_{ij}}{\partial \theta_j}\right)^2}{P_{ij}^2 Q_{ij}^2} (P_{ij} - Q_{ij}) \right] \right] \quad ;$$

---

*The authors are grateful to Kirsten Yocom for verifying all of the derivatives.

where

$$\frac{\partial P_{ij}}{\partial \theta_j} = \frac{(\delta - c_i)Da_i}{e^{DL_{ij}} + 2 + e^{-DL_{ij}}}$$

and

$$\frac{\partial^2 P_{ij}}{\partial \theta_j^2} = \frac{-(\delta - c_i)D^2 a_i^2 (e^{DL_{ij}} - e^{-DL_{ij}})}{(e^{DL_{ij}} + 2 + e^{-DL_{ij}})^2} \quad .$$

Item-parameter derivatives:

We will drop subscripts for brevity in the following formulas.

If χ represents a_i , b_i , or c_i , and ψ represents a_i , b_i , or c_i , then

$$\frac{\partial \ell}{\partial \chi} = \sum_{j=1}^{N} (u - P) \frac{\left(\frac{\partial P}{\partial \chi}\right)}{PQ}$$

and

$$\frac{\partial^2 \ell}{\partial \chi \partial \psi} = \sum_{j=1}^{N} \left[\frac{-\left(\frac{\partial P}{\partial \psi}\right)\left(\frac{\partial P}{\partial \chi}\right)}{PQ} + (u - P)\left[\frac{\left(\frac{\partial^2 P}{\partial \chi \partial \psi}\right)}{PQ} + \left(\frac{\partial P}{\partial \chi}\right)\left(\frac{\partial P}{\partial \psi}\right) \frac{(P - Q)}{P^2 Q^2} \right]\right] \quad ;$$

where

$$\frac{\partial P}{\partial a} = \frac{(\delta - c)D(\theta - b)}{e^{DL} + 2 + e^{-DL}} \quad ,$$

$$\frac{\partial P}{\partial b} = \frac{-(\delta - c)Da}{e^{DL} + 2 + e^{-DL}} \quad ,$$

$$\frac{\partial P}{\partial c} = \frac{1}{1 + e^{DL}} \quad ,$$

$$\frac{\partial^2 P}{\partial a^2} = \frac{-(\delta - c)D^2(\theta - b)^2(e^{DL} - e^{-DL})}{(e^{DL} + 2 + e^{-DL})^2} \quad ,$$

$$\frac{\partial^2 P}{\partial b^2} = \frac{-(\delta - c)D^2a^2(e^{DL} - e^{-DL})}{(e^{DL} + 2 + e^{-DL})^2} \quad ,$$

$$\frac{\partial^2 P}{\partial c^2} = 0 \quad ,$$

$$\frac{\partial^2 P}{\partial a \partial b} = \frac{(\delta - c)D^2a(\theta - b)(e^{DL} - e^{-DL})}{(e^{DL} + 2 + e^{-DL})^2} - \frac{D(\delta - c)}{(e^{DL} + 2 + e^{-DL})} \quad ,$$

$$\frac{\partial^2 P}{\partial a \partial c} = \frac{-D(\theta - b)}{e^{DL} + 2 + e^{-DL}} \quad ,$$

and

$$\frac{\partial^2 P}{\partial b \partial c} = \frac{Da}{e^{DL} + 2 + e^{-DL}} \quad .$$

DISTRIBUTION LIST

Navy

1 Dr. Jack R. Borsting
Provost and Academic Dean
U.S. Naval Postgraduate School
Monterey, CA 93940

1 Dr. Robert Breaux
Code N-711
NAVTRAEQUIPCEN
Orlando, FL 32813

1 Chief of Naval Education and
Training Liason Office
Air Force Human Resource Laboratory
Flying Training Division
Williams Air Force Base, AZ 85224

1 CDR Mike Curran
Office of Naval Research
800 North Quincy Street
Code 270
Arlington, VA 22217

1 Dr. Richard Elster
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Pat Federico
Navy Personnel R & D Center
San Diego, CA 92152

1 Mr. Paul Foley
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. John Ford
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Henry M. Halff
Department of Psychology, C-009
University of California at San Diego
La Jolla, CA 92093

1 Dr. Patrick R. Harrison
Psychology Course Director
Leadership and Law Department (7b)
Division of Professional Development
U.S. Naval Academy
Annapolis, MD 21402

1 CDR Charles W. Hutchins
Naval Air Systems Command Hq.
AIR-340F
Navy Department
Washington, DC 20361

1 CDR Robert S. Kennedy
Head, Human Performance Sciences
Naval Aerospace Medical Research Lab.
Box 29407
New Orleans, LA 70189

1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054

1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508

1 Dr. Kneale Marshall
Scientific Advisor to DCNO(MPT)
OP01T
Washington, DC 20370

1 CAPT Richard L. Martin, USN
Prospective Commanding Officer
USS Carl Vinson (CVN-70)
Newport News Shipbuilding and Drydock
Newport News, VA 23607

1 Dr. James McBride
Navy Personnel R & D Center
San Diego, CA 92152

1 Library, Code P201L
Navy Personnel R & D Center
San Diego, CA 92152

6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390

1 Psychologist
ONR Branch Office
Building 114, Section D
666 Summer Street
Boston, MA 02210

1 Psychologist
ONR Branch Office
536 South Clark Street
Chicago, IL 60605

1 Office of Naval Research
Code 437
800 North Quincy Street
Arlington, VA 22217

5 Personnel and Training Research
Programs
Code 458
Office of Naval Research
Arlington, VA 22217

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Office of the Chief of Naval Operations
Research Development and Studies Branch
OP-115
Washington, DC 20350

1 LT Frank C. Petho, MSC, USN (Ph.D.)
Selection and Training Research Division
Human Performance Sciences Department
Naval Aerospace Medical Resea ch Lab.
Pensacola, FL 32508

1 Dr. Bernard Rimland (03B)
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Worth Scanland, Director
Research, Development, Test
and Evaluation
N-5
Naval Education and Training Command
NAS
Pensacola, FL 32508

1 Dr. Robert G. Smith
Office of Chief of Naval Operations
OP-987H
Washington, DC 20350

1 Dr. Alfred F. Smode
Training Analysis and Evaluation Group
Department of the Navy
Orlando, FL 32813

1 Dr. Richard Sorensen
Navy Personnel R & D Center
San Diego, CA 92152

1 Mr. J. B. Sympson
Naval Personnel R & D Center
San Diego, CA 92152

1 Dr. Ronald Weitzman
Code 54 WZ
Department of Administrative Services
U.S. Naval Postgraduate School
Monterey, CA 93940

1 Dr. Robert Wisher
Code 309
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Martin F. Wiskoff
Navy Personnel R & D Center
San Diego, CA 92152

1 Mr. Ted M. I. Yellen
Technical Information Office
Code 201
Navy Personnel R & D Center
San Diego, CA 92152

Army

1 Technical Director
U.S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Myron Fischl
U.S. Army Research Institute for the
Social and Behavioral Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Dexter Fletcher
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Michael Kaplan
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Milton S. Katz
Training Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Harold F. O'Neil, Jr.
Attn: PERI-OK
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Mr. Robert Ross
U.S. Army Research Institute for
the Social and Behavioral Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Robert Sasmor
U.S. Army Research Institute for
the Social and Behavioral Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Commandant
U.S. Army Institute of Administration
Attn: Dr. Sherrill
Ft. Benjamin Harrison, IN 46256

1 Dr. Frederick Steinheiser
Department of the Navy
Chief of Naval Operations
OP-113
Washington, DC 20350

1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 Air Force Human Resources Laboratory
AFHRL/MPD
Brooks Air Force Base, TX 78235

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks Air Force Base, TX 78235

1 Research and Measurement Division
Research Branch, AFMPC/MPCYPR
Randolph Air Force Base, TX 78148

1 Dr. Malcolm Ree
AFHRL/MP
Brooks Air Force Base, TX 78235

1 Dr. Marty Rockway
Technical Director
AFHRL(OT)
Williams Air Force Base, AZ 58224

Marines

1 Dr. H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 Director, Office of Manpower Utilization
HQ, Marine Corps (MPU)
BCB, Building 2009
Quantico, VA 22134

1 MAJ Michael L. Patrow, USMC
Headquarters, Marine Corps
Code MPI-20
Washington, DC 20380

1 Dr. A. L. Slafkosky
Scientific Advisor
Code RD-1
HQ, U.S. Marine Corps
Washington, DC 20380

Coast Guard

1 Mr. Thomas A. Warm
U.S. Coast Guard Institute
P.O. Substation 18
Oklahoma City, OK 73169

Other DoD

1 DARPA
1400 Wilson Boulevard
Arlington, VA 22209

12 Defense Technical Information Center
Cameron Station, Building 5
Attn: TC
Alexandria, VA 22314

1 Dr. William Graham
Testing Directorate
MEPCOM/MEPCT-P
Ft. Sheridan, IL 60037

1 Military Assistant for Training and Personnel Technology
Office of the Under Secretary of Defense for Research and Engineering
Room 3D129, The Pentagon
Washington, DC 20301

1 Dr. Wayne Sellman
Office of the Assistant Secretary of Defense (MRAL)
2B269 The Pentagon
Washington, DC 20301

Civil Government

1 Dr. Andrew R. Molnar
Science Education Development and Research
National Science Foundation
Washington, DC 20550

1 Dr. Vern W. Urry
Personnel R & D Center
Office of Personnel Management
1900 E Street, NW
Washington, DC 20415

1 Dr. Joseph L. Young, Director
Memory and Cognitive Processes
National Science Foundation
Washington, DC 20550

Non-Government

1 Dr. Erling B. Andersen
Department of Statistics
Studiestraede 6
1455 Copenhagen
DENMARK

1 Psychological Research Unit
Department of Defense (Army Office)
Campbell Park Offices
Canberra, ACT 2600
AUSTRALIA

1 Dr. Isaac Bejar
Educational Testing Service
Princeton, NJ 08541

1 Capt. J. Jean Belanger
Training Development Division
Canadian Forces Training System
CFTSHQ, CFB Trenton
Astra, Ontario KOK 1B0
CANADA

1 Dr. Menucha Birenbaum
School of Education
Tel Aviv University
Tel Aviv, Ramat Aviv 69978
ISRAEL

1 Dr. Werner Birke
DezWPs im Streitkraefteamt
Postfach 20 50 3
D-5300 Bonn 2
WEST GERMANY

1 Liaison Scientists
Office of Naval Research
Branch Office, London
Box 39
FPO, NY 09510

1 Dr. Robert Brennan
American College Testing Programs
P.O. Box 168
Iowa City, IA 52240

1 Dr. C. Victor Bunderson
WICAT Inc.
University Plaza, Suite 10
1160 South State Street
Orem, UT 84057

1 Dr. John B. Carroll
Psychometric Laboratory
University of North Carolina
Davie Hall 013A
Chapel Hill, NC 27514

1 Charles Myers Library
Livingstone House
Livingstone Road
Stratford
London E15 2LJ
ENGLAND

1 Dr. Kenneth E. Clark
College of Arts and Sciences
University of Rochester
River Compus Station
Rochester, NY 14627

1 Dr. Norman Cliff
Department of Psychology
University of Southern California
University Park
Los Angeles, CA 90007

1 Dr. William E. Coffman
Director, Iowa Testing Programs
334 Lindquist Center
University of Iowa
Iowa City, IA 52242

1 Dr. Meredith P. Crawford
American Psychological Association
1200 17th Street, N
Washington, DC 20036

1 Dr. Fritz Drasgow
Yale School of Organization and
Management
Yale University
Box 1A
New Haven, CT 06520

1 Dr. Mavin D. Dunnette
Personnel Decisions Research Institute
2415 Foshay Tower
821 Marguette Avenue
Minneapolis, MN 55402

1 Mr. Mike Durmeyer
Instructional Program Development
Building 90
NET-PDCD
Great Lakes NTC, IL 60088

1 ERIC Facility-Acquisitions
4833 Rugby Avenue
Bethesda, MD 20014

1 Dr. Benjamin A. Fairbank, Jr.
McFann-Gray and Associates, Inc.
5825 Callaghan
Suite 225
San Antonio, TX 78228

1 Dr. Leonard Feldt
Lindquist Center for Measurement
University of Iowa
Iowa City, IA 52242

1 Dr. Richard L. Ferguson
The American College Testing Program
P.O. Box 168
Iowa City, IA 52240

1 Dr. Victor Fields
Department of Psychology
Montgomery College
Rockville, MD 20850

1 Univ. Prof. Dr. Gerhard Fischer
Psychologisches Institut der
Universitat Wien
Liebiggasse 5/3
A 1010 Wien
AUSTRIA

1 Prof. Donald Fitzgerald
University of New England
Armidale, New South Wales 2351
AUSTRALIA

1 Dr. Edwin A. Fleishman
Advanced Research Resources Organization
Suite 900
4330 East West Highway
Washington, DC 20014

1 Dr. John R. Frederiksen
Bolt, Beranek, and Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Robert Glaser
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. Bert Green
Department of Psychology
Johns Hopkins University
Charles and 34th Streets
Baltimore, MD 21218

1 Dr. Ron Hambleton
School of Education
University of Massachusetts
Amherst, MA 01002

1 Dr. Chester Harris
School of Education
University of California
Santa Barbara, CA 93106

1 Dr. Lloyd Humphreys
Department of Psychology
University of Illinois
Champaign, IL 61820

1 Library
HumRRO/Western Division
27857 Berwick Drive
Carmel, CA 93921

1 Dr. Steven Hunka
Department of Education
University of Alberta
Edmonton, Alberta
CANADA

1 Dr. Earl Hunt
Department of Psychology
University of Washington
Seattle, WA 98105

1 Dr. Huynh Huynh
College of Education
University of South Carolina
Columbia, SC 29208

1 Prof. John A. Keats
Department of Psychology
University of Newcastle
Newcastle, New South Wales
AUSTRALIA

1 Mr. Marlin Kroger
1117 Via Goleta
Palos Verdes Estates, CA 90274

1 Dr. Michael Levine
Department of Educational Psychology
210 Education Building
University of Illinois
Champaign, IL 61801

1 Dr. Charles Lewis
Faculteit Sociale Wetenschappen
Rijksuniversiteit Groningen
Oude Boteringestraat 23
9712GC Groningen
NETHERLANDS

1 Dr. Robert Linn
College of Education
University of Illinois
Urbana, IL 61801

1 Dr. Frederic M. Lord
Educational Testing Service
Princeton, NJ 08541

1 Mr. Merl Malehorn
Department of Navy
Chief of Naval Operations
OP-113
Washington, DC 20350

1 Dr. Gary Marco
Educational Testing Service
Princeton, NJ 08541

1 Dr. Scott Maxwell
Department of Psychology
University of Houston
Houston, TX 77004

1 Dr. Samuel T. Mayo
Loyola University of Chicago
820 North Michigan Avenue
Chicago, IL 60611

1 Mr. Bill Nordbrock
Instructional Program Development
Building 90
NET-PDCD
Great Lakes NTC, IL 60088

1 Dr. Melvin R. Novick
356 Lindquist Center for Measurement
University of Iowa
Iowa City, IA 52242

1 Dr. Jesse Orlansky
Institute for Defense Analyses
400 Army Navy Drive
Arlington, VA 22202

1 Dr. James A. Paulson
Portland State University
P.O. Box 751
Portland, OR 97207

1 Mr. Luigi Petrullo
2431 North Edgewood Street
Arlington, VA 22207

1 Dr. Diane M. Ramsey-Klee
R-K Research and System Design
3947 Ridgemont Drive
Malibu, CA 90265

1 Mr. Minrat M. L. Rauch
P II 4
Bundesministerium der Verteidigung
Postfach 1328
D-53 Bonn 1
GERMANY

1 Dr. Mark D. Reckase
Educational Psychology Department
University of Missouri-Columbia
4 Hill Hall
Columbia, MO 65211

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson Street, NW
Washington, DC 20007

1 Dr. Leonard L. Rosenbaum, Chairman
Department of Psychology
Montgomery College
Rockville, MD 20850

1 Dr. Ernst Z. Rothkopf
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974

1 Dr. Lawrence Rudner
403 Elm Avenue
Takoma Park, MD 20012

1 Dr. J. Ryan
Department of Education
University of South Carolina
Columbia, SC 29208

1 Prof. Fumiko Samejima
Department of Psychology
University of Tennessee
Knoxville, TN 37916

1 Dr. Robert J. Seidel
Instructional Technology Group
HumRRO
300 North Washington Street
Alexandria, VA 22314

1 Dr. Kazuo Shigemasu
University of Tohoku
Department of Educational Psychology
Kawauchi, Sendai 980
JAPAN

1 Dr. Edwin Shirkey
Department of Psychology
University of Central Florida
Orlando, FL 32816

1 Dr. Robert Smith
Department of Computer Science
Rutgers University
New Brunswick, NJ 08903

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

1 Dr. Robert Sternberg
Department of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Patrick Suppes
Institute for Mathematical Studies
in the Social Sciences
Stanford University
Stanford, CA 94305

1 Dr. Hariharan Swaminathan
Laboratory of Psychometric and
Evaluation Research
School of Education
University of Massacuusetts
Amherst, MA 01003

1 Dr. Kikumi Tatsuoka
Computer Based Education Research
Laboratory
252 Engineering Research Laboratory
University of Illinois
Urbana, IL 61801

1 Dr. David Thissen
Department of Psychology
University of Kansas
Lawrence, KS 66044

1 Dr. Robert Tsutakawa
Department of Statistics
University of Missouri
Columbia, MO 65201

1 Dr. J. Uhlaner
Perceptronics, Inc.
6271 Variel Avenue
Woodland Hills, CA 91364

1 Dr. Howard Wainer
Educational Testing Service
Princeton, NJ 08541

1 Dr. Phyllis Weaver
Graduate School of Education
Harvard University
200 Larsen Hall, Appian Way
Cambridge, MA 02138

1 Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 East River Road
Minneapolis, MN 55455

1 Dr. Susan E. Whitely
Psychology Department
University of Kansas
Lawrence, KS 66044

1 Dr. Wolfgang Wildgrube
Streitkraefteamt
Box 20 50 03
D-5300 Bonn 2
WEST GERMANY

ILMED

8